INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: **EFFECTIVE UTILIZATION OF DATA FOR ENHANCING THE PERFORMANCE OF MANUFACTURING**

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Thesis Submitted to the Department/ Center	:	Department of Mechanical Engineering
Date of completion of Thesis Viva-Voce Exam	:	14/01/2024
Key words for description of Thesis Work	:	Data-analytics, cutting force, surface roughness, dynamic reliability, Cook's distance, multiple-linear regression, outliers, turning, machining, open-die forging, closed-die forging, finite element method, forging load, friction, interval estimation, similarity index, fuzzy set, Kalman filter

SHORT ABSTRACT

The effective utilization of data is becoming increasingly important for enhancing the performance of manufacturing processes. In the era of Industry 4.0, advancements in technology have enabled the collection of vast amounts of data from various manufacturing processes, making it possible to analyze the data and derive insights that can help enhance the performance. One of the main advantages of using data-driven manufacturing is the ability to identify quality issues early in the production process. It reduces the likelihood of defective products, thereby enhancing customer satisfaction, reducing wastage and improving the profitability.

Literature review indicates that modelling of manufacturing processes using physics-based techniques requires unrealistic assumptions and complete knowledge of the deformation phenomenon. With the advancement in the computational capabilities, numerical techniques provide some hope. However, for complex geometries, numerical simulations take up several hours to complete and the associated computational cost also increases. In the era of Industry 4.0, data-driven models can be an alternative way to model a manufacturing process. It provides a quick and accurate estimation. An efficient data-driven modelling of manufacturing process can be achieved by focusing on building a reliable data bank, filtering out the noisy data and avoiding data explosion.

To explore the feasibility of data-driven manufacturing, two typical manufacturing process are considered, viz., turning and forging. Turning is a representative conventional machining process and forging is a typical example of bulk metal forming process. The first objective of the thesis is focused on capturing veracious data and identification of outliers in turning. The strategy is explained by giving an example of cutting force estimation in turning operation. It attempts to utilize the concept of data analytics for collecting and building a data warehouse, termed as Central Database Repository (CDR). CDR uses multiple linear regression on the captured data and preserved in the databank. Uncertainties associated during machining are taken care of in a separate cloud-based repository termed as mini-repository. Cutting force estimation is carried out with 95% confidence and a new concept of dynamic reliability is attached with each data. Moreover, there is a provision to update the database based on the feedback and filter out the unnecessary data by evaluating the Cook's distance.

The second objective of the thesis aims towards efficient storage and prediction, thereby avoiding data explosion in turning. The methodology is explained by giving an example of surface roughness estimation in turning operation using an industrial big data. The main aim is to preserve the essential model parameters rather than the complete data so that the burden on data storage is reduced. The scheme suggests the lower, most-likely and upper estimates of the surface roughness using 35000 datasets simulated using a virtual lathe. The complete region of data is divided into 81 cells and model fitting is carried out in each cell. The proposed methodology provides a reasonable accuracy in the estimation of surface roughness.

The third objective focusses on efficient utilization of the shop floor data for forging load estimation. The main focus is on using an empirical model for estimating the forging load in open and closed die forging. The empirical approach requires correct estimation of a correction factor termed as complexity factor. The complexity factor depends on the geometry of the product and the friction condition. All the data for validations is obtained from finite element method (FEM) simulations using ABAQUS®, that represents a virtual factory. For open die forging, the value of the complexity factor can be accurately estimated using a semi-analytical approach irrespective of the aspect ratio. However, the challenge lies in accurately suggesting the complexity factor for closed die forged products. A methodology is suggested for estimating the forging load in axisymmetric closed-die forged products using a fuzzy set-based methodology. Estimations are carried out using the most similar products in the database.

The last objective attempts to filter the noise from the shop floor data for improving the estimation of the forging load. Kalman filter is used to filter the noise from the shop floor data. In this case, both closed-die forged axisymmetric as well as non-axisymmetric products are considered. All the information is preserved in MySQL relational database. A novel feature of this work is that instead of one deterministic estimate, three estimates, viz. lower, upper and most likely, are obtained. There is also a provision for updating the preserved information in the database. Typical case studies are presented to show the fine tuning of the suggested forging load. When forging load is estimated under stable condition, Kalman filter helps in reducing the error drastically. When forging load is estimated under unstable condition, Kalman filter tries to follow the most-likely estimate.

Overall, the effective utilization of data is presented for two typical manufacturing processes, viz., turning and forging. A well-structured methodology is presented for preserving the veracious data by identifying the outliers. Data duplication is avoided and performance estimation if carried out by preserving only the model parameters, thereby reducing the chances of data explosion. Closed-die forging load is estimated by retrieving the information of the most similar product. Uncertain parameters are represented as fuzzy parameters. Kalman filter is used for tuning the estimate of a semi-analytical model.